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STABILIZATION OF SOIL BY SILT INJECTION METHOD

by George E. Johnson, M. ASCE

SOIL MECHANICS AND FOUNDATIONS DIVISION

(Discussion open until March 1, 1954)

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THE STABILIZATION OF SOIL BY THE SILT INJECTION METHOD FOR PREVENTING SETTLEMENT OF HYDRAULIC STRUCTURES AND LEAKAGE FROM CANALS

George E. Johnson,
M - ASCE
Chief Engineer of The Central Nebraska Public Power
and Irrigation District, Hastings, Nebraska

SYNOPSIS

This paper presents a method for consolidating Loess or other porous soils by pumping a silt slurry into the moist soil. The success of this method of consolidation primarily depends upon the soil having sufficient porosity to serve as a filter, allowing the moisture in the soil and water in a slurry to be forced out through the soil surrounding the area being consolidated.

INTRODUCTION

The use of a silt slurry under pressure to jack up low spots in concrete pavement has been standard practice for several years. However, at the beginning of the work herein described there was no information available on consolidation of Loess Soil with a silt slurry and very little information available on the action of dry unconsolidated Loess Soil when used as a foundation for hydraulic structures. Field and laboratory tests revealed this undisturbed soil had a great deal more vertical seepage than horizontal seepage, and the soil, when saturated, would consolidate and settle several feet under the weight of the structures.

The tests also showed this soil, when consolidated, would make a safe foundation and the movement of the grains of soil during consolidation would close the pores sufficiently to prevent excessive leakage.

A general statement of the problems involved and methods considered and used are described.

Outline of Project

The Central Nebraska Public Power and Irrigation District, locally referred to as "Tri-County", is a political subdivision of the State of Nebraska, consisting of Gosper, Phelps, Kearney and Adams Counties. The properties of the District extend from Ogallala, Nebraska, east to Lincoln, Nebraska -- distance of approximately three hundred miles.

The District was organized for the purpose of supplying water for irrigation and the generation and transmission of hydroelectric power. The project was financed through the Public Works Administration at a cost of $43,000,000.00.

Location of Project

The location of the project is shown on Drawing P-8. Water is stored in the reservoir back of Kingsley Dam, which dam impounds 1,948,000 acre feet.

Water is released through Kingsley Dam and carried down the North Platte River, or through the canal and reservoirs of the Platte Valley Public Power and Irrigation District to the Upper Diversion Dam of Tri-County, which is located at the confluence of the North and South Platte Rivers, approximately 50 miles east of Kingsley Dam. The water is then carried through the Tri-County Supply Canal and twenty-six small reservoirs.

The total distance through the canal and reservoirs is seventy-six miles. The canal was designed to carry 2,500 cubic feet of water per second, with a fall of four-tenths of a foot per mile. The two wasteways to the Platte River are located east of the towns of Brady and Lexington, Nebraska.

The irrigation section of the project, as constructed, extends from a short distance east of Elwood, Nebraska, to a point northeast of Minden, Nebraska. It is now supplying water to approximately 110,000 acres. The irrigated section is supplied with water from the Phelps County Canal and Lateral E-65, with approximately five hundred miles of small laterals.

Problems Developed From Field and Laboratory Tests

Field investigations and laboratory tests made prior to construction revealed the sand and gravel stratum of the Platte River bed extended under the entire area where work was to be performed. This gravel is overlaid the entire distance with Loess Soil, having numerous sand pockets and sand lenses. The Loess was laid down by the wind in two or more different periods.

The Loess laid down during the first period appears to have been quite level, except as it slopes toward the streams with a gradual slope to the southeast. Erosion developed deep canyons which were refilled at a later date. The weight of the Loess fills in these canyons, where Loess Soil was deposited at a later period, is from two to five pounds less per cubic foot than the original Loess deposits. Studies also revealed the average unit weight of the Loess Soil in place from the original Loveland Loess deposits was about 85 to 87 pounds; the deposits of Peorian Loess averaging from 75 to 83 pounds per cubic foot. Some of the wind-blown or re-worked soil has a unit weight as low as 66.8 pounds. All of this soil, when completely saturated, will slump. When dried after the slump or consolidation under pressure, a large portion of this soil will weigh from 15 to 20 per cent more per cubic foot than the dry weight of the undisturbed samples. The amount of slump as consolidation takes place depends principally on the density and percentage of sand and clay with the Loess.

Our tests revealed when concrete structures, canals, dams and reservoirs were constructed on this soil, a considerable amount of saturation and settlement would take place. Laboratory and field work indicated this settlement would not be uniform for rolled fill dams. The extreme bottom of the canyons had been partially saturated and part of the settlement had already taken place. On each side of the canyon above the flood line, the soil had not been saturated and would take full settlement after being saturated and loaded. Also, as these dams tapered off at the ends, we would have a depreciating amount of weight in the fill, and a greater thickness of undisturbed Loess. This condition would also cause uneven settlement. We knew the standard methods of constructed rolled fill dams would not give us structures which would stand this uneven

settlement without cracking. It was necessary to construct a large number of heavy concrete structures. The soil under these structures would be saturated, and unless special precautions were taken, these structures would settle from three to seven feet. When considering these problems together with the fact that a very large part of this settlement would take place with the water back of the dams and around the structures, we realized we had a dangerous problem, which must be solved, or it would be necessary to abandon the construction of the project.

Plate #1, attached, shows curves of particle size of six representative samples of Loess Soil of the Supply Canal.

Methods Considered for Consolidation of Soil

We first considered installing pumps and saturating the foundations for preconsolidation, but our field investigations showed we would not get full settlement by preconsolidation as cavities would develop with saturation. The full slump and consolidation would not take place without loading. Field investigations were continued until we were satisfied we could partially saturate this Loess Soil with water from the canal after the structures were completed, and allow the water to seep down until it reached the sand and gravel without causing settlement of the structures. Then before the water table began to rise, bore down to sand with drilling equipment and inject a slurry of Peorian Loess to consolidate this moist Loess sufficiently to support the structures as the water table rises. The average Loess Soil would retain from 22 to 28 per cent moisture. The surplus moisture would seep down and complete saturation was about 33 per cent. Also, studies showed the moisture retained in the soil was sufficient to consolidate this soil with pressure from mud pumps.

We have a different problem if we are interested only in stabilizing soil to carry a load, than if we were also required to prevent seepage from water pressure. The fine sand content of the slurry can be much greater if we are only interested in stability. We must have sufficient fine silt or clay in the slurry to fill the voids of the sand to prevent excessive leakage when the soil is under water pressure. We also have the practical problem of carrying the slurry along the deep fills of the canal banks and injecting the slurry into a large number of injection pipes, which is a different problem than doing this work on a small area.

Movement of Soil and Water by Silt Injection

Many people have asked where does the water go and what happens when we pump a silt slurry in the ground. This question should be answered before we discuss the work we have done. There are several requirements which must be met if we are to be successful with a silt injection program. These requirements are as follows:

1. The soil must be sufficiently porous to serve as a filter to allow the excess water to move out under pressure.
2. The slurry being pumped in must be sufficiently porous to allow the water to move under pressure through the slurry when the walls of the filter begin to hold the solids of the slurry.
3. The slurry must have sufficient fines to lubricate the mixture sufficiently to be pumped in place.

4. Sufficient water to liquify the mixture.

5. The injection must be made at a sufficient depth to insure consolidation.

6. It is necessary to have sufficient thickness of soil or weight above the silt injection work, as the less the weight, the more applications are required for consolidation, which increases the cost.

7. Sufficient equipment to mix and deliver the slurry to the injection pipes at the proper pressure.

Our engineers have prepared two plates, #2 and #3, which are attached and indicate what takes place when we pump a silt slurry into the ground. The densities show the slurry as it leaves the injection pipe, moves out against the least resistance, and as the water is filtered out, the soil becomes more dense until it is finally consolidated sufficiently to prevent excess seepage or settlement under structures. If the soil will not pass the water out under pressure, the mass will remain liquid, and if injection work continues under these conditions, there is certain to be a failure. For this reason, an engineer before starting any extensive silt injection work, should make enough tests in the field to be certain the soil will consolidate with the slurry that can be developed with local materials.

Method Developed for Doing the Work

When developing the information from our settlement plate tests, we found it necessary to begin our consolidation work before the water table began to rise. For that reason, where we had considerable distance between the bottom of the heavier concrete structures and sand, this work was started when the moisture penetrated down half the distance to the sand. Silt injection was started at the upstream end of the structure by going down with 2 four-inch holes back of the two wing walls where they join the body of the structure -- one hole on each side of the structure. In each of these holes, a two-inch pipe was inserted with a packer at the end of the pipe located a short distance below the bottom of the structure. On the first work, a mixture of 5% Bentoinite and 95% Peorian Loess Soil, mixed with 40% water into a thick slurry, was pumped in at pressures from 125 to 150 pounds per square inch. The shearing strength of the soil would stand this pressure, and no difficulty was experienced from uplift of the structures. After considerable experimenting, it was found sufficient Loess Soil of the proper particle size was available, and it was better not to use Bentonite, as the Bentonite would cause the water to be entrapped in the slurry.

It is not advisable to pump in more than two holes on one concrete structure at the same time because of the danger of uplift of the structure or blowout of the soil. Naturally, it will be necessary to reduce this pressure on very small structures or where compaction is required near the surface of the soil. Maximum pressure can easily be determined by use of an engineer's level, checking the structure for uplift at the time the pumping is being done. After some experimentation, we found it was not necessary to use a rubber packer on the slurry pipe as satisfactory results were obtained with burlap wrapped around and clamped to the pipe.

Bench marks were established at the time of construction and elevations were checked at different points on the structures during different periods of pumping. By carefully following this method of checking during the period of consolidation, no difficulty has been experienced with movement or settlement of the structures. We have checked these structures two or more times and

have taken samples. Upon finding soft materials in the earth stratum below or around the structure, more slurry was pumped in. At first, our holes and injection pipes were not more than six feet apart along the side of the concrete structure. Our practice was to follow on opposite sides of the structure pumping in one hole on each side at the same time so the forces would balance under the structure while consolidation was taking place. The reason it has been necessary to go back to these structures for additional consolidation is because the first work done took place before the moisture reached the sand.

On this original work, we pumped from 12 to 20 cubic yards of slurry into each injection pipe. This does not mean there were cavities of that size. When the soil is partially saturated, using the pressure above stated, the soil can be moved and consolidated, so additional material can be added. When this job is done properly, in soil that will filter out the water, the completed soil boring show a consolidation equivalent to compacted fill.

In some cases, after construction work had been completed, seepage developed below the high compacted fills along the canal, especially at the headworks of two power houses. The most noticable example was at the Johnson #1 Power House, where in order to reduce the length of the penstocks,a rolled fill for the supply canal was constructed one-half mile long between the regulating reservoir and the headworks for the power house. At this point, it is approximately 105 feet from the water level of this canal down through Peorian Loess to sand. Slumping of the Loess Soil took place under the rolled fill for a considerable distance along the canal. The seepage from the canal collected in channels produced by this slumping and was carried along below the cut-off trenches of each side of the headworks, where the Loess had previously been consolidated. Our first indication of trouble was water seeping out around the headworks. The saturation of the natural soil under the rolled fill had developed to a point where holes bored in the soil caved and closed at a depth of about 45 feet. We bored down as far as the walls of the hole would stand, and set up the mud pumps to use as much pressure as was possible under these conditions, which pressure averaged from 50 to 100 pounds per square inch. This work consolidated the Loess Soil from the bottom of the rolled fill to a point 10 to 25 feet below the bottom of the hole. We then bored in near the first hole, and were able to go down 10 to 25 feet deeper with the second hole. This work was carried on, repeating this method until we were down to the depth desired for complete consolidation. From that point on, by boring in the partially consolidated material, we carried on the work continuously with holes bored the full depth, 6 to 10 feet apart, paralleling the canal until the seepage ceased.

Silt Injection on Rolled Fill Dams

For the rolled fill dams, a series of experiments was carried on in the laboratory. We found by increasing the moisture in the rolled fills to approximately 2% above the optimum, sufficient ductility was secured so the dams would take the uneven settlement without breaking up. Also, this moisture could be increased 2% without any danger of slumping after the reservoirs were filled with water. For construction of the rolled fills, a specification was prepared based on the laboratory work, which gave satisfactory compacted embankment for the fills.

After the dams were constructed, and sufficient saturation had taken place in the Loess Soil under the dams and the settlement started, holes were bored along the upstream and downstream slopes of the dam, and silt slurry was injected. This reduced the settlement on these dams to about one-half of that

which our settlement tests showed would have taken place, if no consolidation work had been done. The depth of water back of these dams is from 40 to 74 feet.

Plate No. XIV, Glen Young Dam, shows an average condition of the natural soil which serves as a foundation for these dams.

All the consolidation work was carried on as a part of our regular maintenance program and was maintained from the time this project went into operation in 1941 until the end of 1945. No settlement had taken place at any of the concrete structures during this period. During the years from the beginning of 1946 to October, 1950, very little silt injection work was done.

Expanded Program Started March 1, 1951

Prior to October 1, 1950, all the silt injection work was done by pumping into a single injection pipe with each pump.

In the fall of 1950, we found several large cavities under our heavy fills along the canal. Each of these cavities required from 100 to 300 cubic yards of soil to fill. The seepage from the Supply Canal had increased until our seepage was averaging above 225,000 acre feet per year, or approximately 20% of the total water diverted from the river into the canal. We worked out a program for silt injection to fill these cavities and seal the sections of the canal having excessive seepage which sections covered a total of approximately 40 miles. Part of this work was to be done on both sides of the canal, and due to different soil conditions, a part of the work was on one side only.

To develop this program, we experimented with pumping different densities of slurry through hose lines, and found we could use the Peorian Loess where the clay and colloids were from 10 to 16 per cent. The sand settling out on the standard hydrometer test at 40 seconds was between 20 and 26 per cent. With the Loess Soil, we mix water of equal weight to the dry soil, or a 50 - 50 mixture. We designed and constructed two slurry mixers and re-worked some water and gravel pumps. We cut the diameter of impellers of 6" gravel pumps from 24 to 15 inches, metalized the shafting in the stuffing boxes with hard stainless steel, connected the two gravel pumps in series and increased their speed from 900 to 1500 RPM.

We metalized the shafting of the water pumps used as boosters, changed the brass impellers to cast iron, and connected high pressure clear water on all the stuffing boxes not less than 50 pounds above the silt pressure on the stuffing boxes.

We tried several experiments with making the silt wells, and sealing the injection pipes. In March, 1951, we found the best method was to drill the holes to sand or gravel, use an injection pipe not less than 1-1/2"ID. If the hole is more than 45 feet deep, the injection pipes should not be less than 40 feet long. If less than 45 feet, place bottom of injection pipe 5 feet from bottom of hole. If the hole is 90 feet or more, we generally use 60 feet of pipe. For the rolled fill dams, we place the end of the pipe about 20 feet below the bottom cut-off trench of the dam. Before placing the injection pipe in the hole, we wrap the lower two feet with burlap sufficient to fill the hole, then lace a wire around the lower half of the burlap, wire to be hooked over end of pipe, then split the top half of burlap in three places, push the pipe down the hole, fill first five feet with moist soil and remainder of hole with gravel and tamp each foot of gravel, then connect injection pipe to hose carrying slurry. When pressure rises on the gauge at the top of the injection pipe equal to pressure on the hose line used as header, the slurry has consolidated in the

injection pipe. To remove this consolidated material, first remove connection from top of injection pipe, then use a 3/4 inch hose with ten feet of 3/4 inch pipe on the lower end of hose and jet out the pipe with slurry from the header. If injection pipe less than 1-1/2 ID is used, it will be difficult to use a jet in the pipe. Double strength pipe should be used, and jacks or a winch truck with 30 ton lifting capacity will be required to pull the injection pipe.

Plate XX, attached, shows the layout of the equipment set up for silt injection of two miles on one side of canal bank.

Plate XXI, attached, shows a detailed drawing of a slurry mixer. This drawing does not show the covers to be placed over the exposed moving parts. These covers are required for safe operation.

If the set-up is changed to one mile on each side of the canal, the mixing equipment is set to pump one-half mile in each direction, and the booster pumps are eliminated.

During 1951, we provided one 2-1/2" hose connection and Henzy Flow Meter from the header for three silt injection pipes, or 1/3 the number of connections as there were silt injection pipes to be served. We found by experiments made in September, we did better work with less slurry if we maintained a feed not in excess of 15 gpm, except where we had cavities. Three feet of 1/2 inch pipe with 100 pounds of pressure will give us approximately 15 gpm of 50 - 50 mixture, and no experience or judgement is required by the operator, as he opens the valve wide open. Also, if there are no cavities and we have only the problem of consolidation, with 15 gpm we eliminate the water through the Loess without excessive pressures. We also save the wear or erosion on the valve. If we have a cavity, which we average about three per mile, we take off the small connection and attach a 2-1/2"hose with a Henzy Flow Meter. The large connection allows us to increase the flow to 100 gpm. We do not pump into all the injection pipes at one time.

This year we connected onto 200 injection pipes at the same time, operating one valve of each four connections, or 50 at one time. Fifty pipes at 15 gpm gives us 750 gpm of 50 - 50 mix, or approximately 100 cubic yards per hour of silt injected.

The program of not pumping slurry into adjacent injection pipes at the same time and later pumping into the pipes between the first pipes used moves the soil in alternate directions, breaks up the sand lenses and puddles the soil.

We use a 300 pound pressure gauge at the top of each injection pipe. Along the canal bank we do not try to get more than 100 pounds of pressure. Under the larger concrete structures and the rolled fill dams, we raise the pressure up to 250 psi.

Silt Injection Work on Irrigation System

Our irrigation system carries water during approximately six months of each year. At the beginning of our operations we stabilized the concrete structures of the irrigation canals in the same manner as described above for the Supply Canal. Since that time, each year as the canals are drained, an inspection is made. Where we find silt injection work is necessary, the work is performed while the soil is still moist and in condition for compaction.

The average thickness of the Loess Soil in our irrigation system is in excess of 100 feet. There is also a layer of gravel immediately below the Loess Soil of 100 feet. This layer of gravel was formerly a part of the bed of the Platte River. There is a movement of water from the Platte River to the Republican River under this entire area. The seepage from our irrigation system has caused very little increase in the elevation of our water table of

this area.

Our experience shows there is an advantage in doing silt injection work at the proper time. It is necessary that the consolidation work be started before the water table begins to rise to prevent structures from settling, especially if the dry weight of the soil is less than 80 pounds per cubic foot. Under fills on canal banks, if the work is delayed and the water has seeped out a considerable distance, the soil will move farther when compaction begins, requiring more slurry for the compaction work. The most satisfactory and economical silt injection work can be done by outlining the program in advance of construction, and follow up with the work of compaction after construction as the soil takes up sufficient moisture to be compacted.

When considering the use of silt injection for consolidation of Loess or similar soils, it is first necessary to determine by laboratory and field tests the results which can be secured by this method of consolidation. If the soil is composed of a large per cent of collodial material, which will prevent the water being squeezed out of the soil, then the soil will remain liquid and consolidation will not take place. If the mechanical analysis and laboratory work indicates the soil would allow the water to be squeezed out under pressure, then field tests should be made to determine the results.

We cannot over-emphasize the importance of the above paragraph. This method of consolidation of soil depends upon being able to squeeze the water out of the soil. Careful tests should be made, and the engineer be certain he is working with a soil that will consolidate under the pressures that are practical to use for the silt injection method of consolidation.

Taking Soil Samples and Making Field Tests Prior to Silt Injection

In taking soil samples, it is very important all thin clay, silt or sand layers encountered be recorded. When the project is placed in operation, these locations should be examined for perched water tables. Several places where thin impermeable silt layers occur under a sand lens, perched water tables have developed. If such areas occur a short distance below a concrete structure, there is danger of the water table rising very soon after operations are started, causing the structure to settle before the seepage has reached the existing water table of the area.

The field tests on consolidation should be made by selecting the same type of soil that is to be consolidated. Bore down not less than ten feet below the depth of the structure to be estabilized with four holes on a square of six feet, run water into these holes, maintaining water at a level equal to the bottom of the structure to be stabilized until the soil is thoroughly moist to the bottom, and then bore a hole in the center of the four holes to the sand for the injection pipe. It may require several days of percolation to get proper moisture distribution before the injection pipe is inserted. The injection pipe should be installed in the same manner as previously specified.

For such tests, it is better to use a slurry as thick as can be pumped, when the pressure indicates the consolidation is complete, then jet out at least five feet below the end of the pipe and try again to make certain that consolidation is complete. If the slurry breaks out, let it rest for a day and try again. It will probably be necessary to make at least four injections before you build up proper density to support the structure.

Reduction in Seepage Loss Due to Work Completed in 1951

We completed approximately 50% of the silt injection work required on our Supply Canal between March 1 and November 1, 1951. Our engineers find we have reduced the total seepage approximately 1/3. We believe when we have completed our work at the end of 1952, we will have reduced our seepage an additional 1/3, making a total reduction of approximately 2/3 of our seepage, or approximately 150,000 acre feet of water a year.

Costs

Our costs for the silt injection program for 1951 were $351,000.00 Our estimate of costs for 1952 is $255,000.00, making a total cost of $606,000.00 for the two-year program.

The total amount of silt injected in the work covered by the 1951 program was 109,295 cubic yards of soil, measurement taken of the soil as excavated.

Attached Photographs

Following is a brief description of the six photographs attached to the last page of this report;

Photograph No. 1 shows the drills at work, drilling the silt wells and placing the injection pipes.

Photograph No. 2 shows the spoil bank along the side of the canal and the equipment loading trucks, each truck carrying approximately 4-1/2 cubic yards.

Photograph No. 3 is a set-up of the mixing and primary pumping equipment. The background of the picture shows the truck ready to unload into the feeder. The silt is then carried from the feeder through the conveyor to the mixer. As slurry is mixed, it is conducted into a pit between the mixer and pumps. Two six-inch pumps in series pump the slurry from the pit into 2 three-inch hose lines that serve as headers.

Photograph No. 4 shows a header in operation along the bank of the canal and connections from the header to the injection pipes.

Photograph No. 5 shows a close-up of the connection to the silt well. The meters shown register up to 150 gallons of silt per minute. It will be noted, this silt well is operated with the valve wide open, and at full capacity at the time the photograph was taken. The pressure gauge indicated the operating pressure on the injection pipe.

Photograph No. 6 shows the pipe pulling equipment in operation. Thirty tons' capacity is required to pull this pipe. This rig was designed so the vertical legs of the tri-pod have a bearing on blocks placed on the ground. By using this method when the pull is made, the springs allow the tri-pod to settle, coming in contact with the blocks, and in this way the blocks take practically all the pressure. Also, as the pressure is released, the springs lift the tri-pod, the

blocks are removed, and the tri-pod has sufficient clearance from the roadway so the truck may be driven forward without interference from the tri-pod. These vertical legs are hinged to the backend of the truck, and the third leg is telescoped. This allows the tri-pod to be lowered forward and the pulling rig can be driven on the public highways.

Acknowledgements

Mr. W. J. Turnbull, Member of ASCE, had charge of all of the original field and laboratory investigations, and assisted on this work until September 16, 1941.

Mr. R. O. Green, Member of ASCE, was Assistant Chief Engineer and had charge of all engineering in the field and supervision of construction. Also, operation of the hydraulic system until October 7,1946.

Mr. Ted.A. Johnson, Member of ASCE, has had direct charge in the field of the silt injection work from March 12, 1951 to this date.

Several representatives of the United States Bureau of Reclamation have observed the work, and the Bureau has made tests on some of this work.

THE CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
TRI-COUNTY PROJECT P.W.A. D-3400R

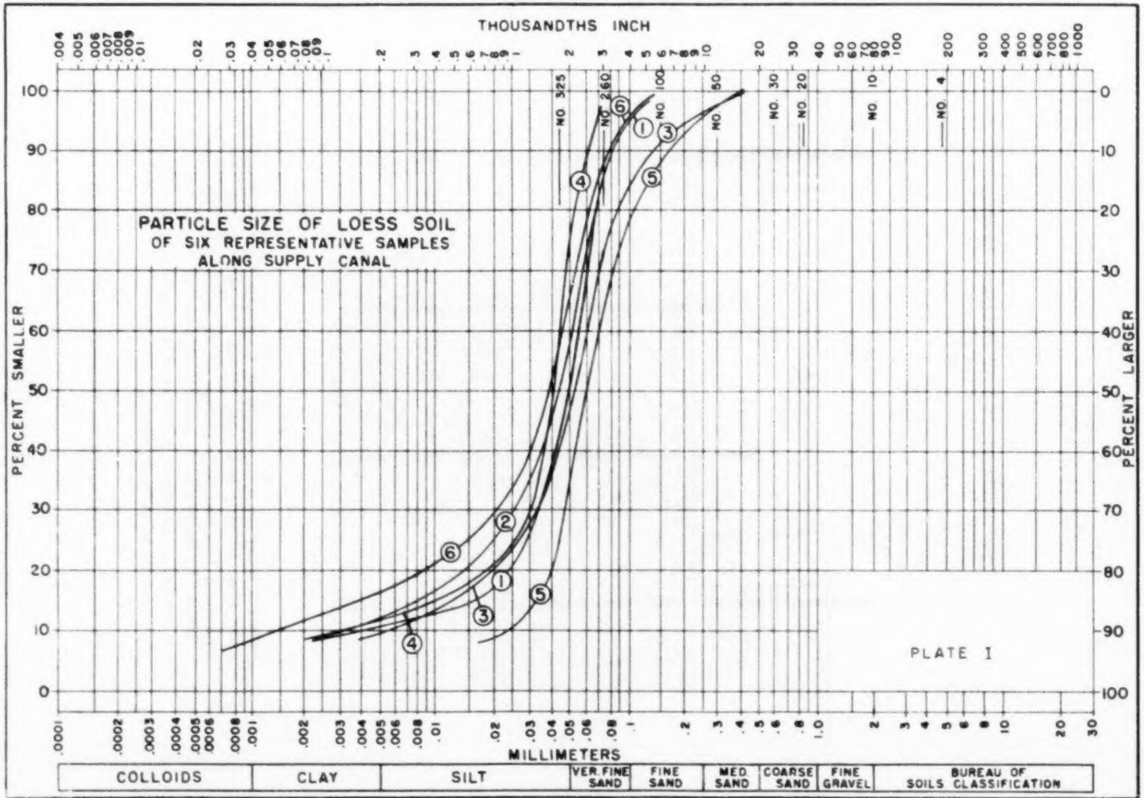


PLATE II

Cross-section of Concrete Headworks Structure

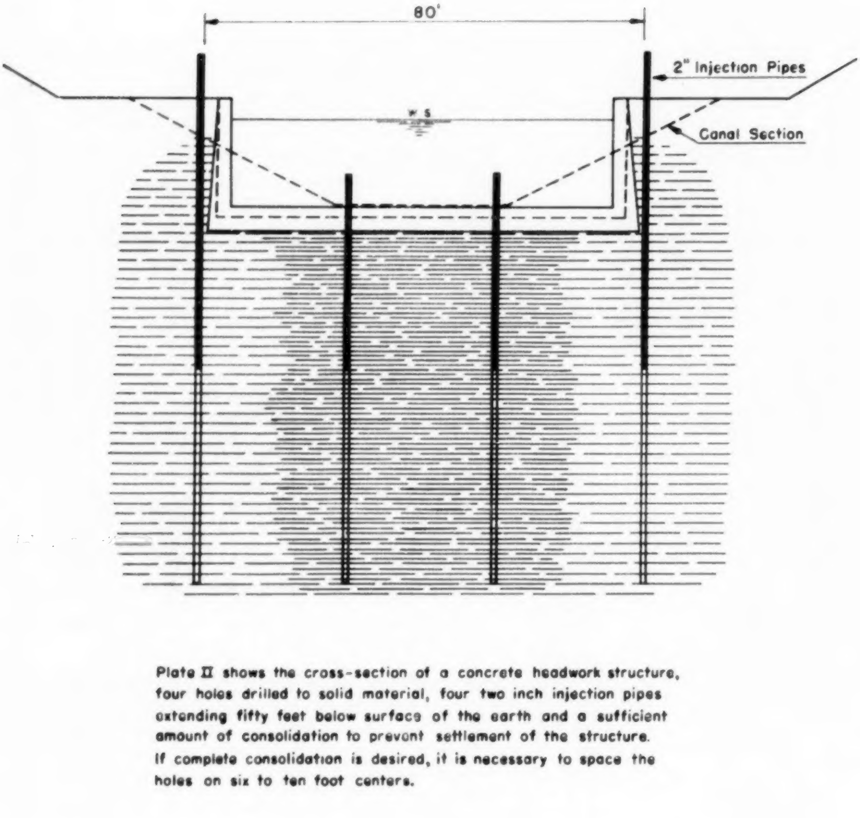


Plate II shows the cross-section of a concrete headwork structure, four holes drilled to solid material, four two inch injection pipes extending fifty feet below surface of the earth and a sufficient amount of consolidation to prevent settlement of the structure. If complete consolidation is desired, it is necessary to space the holes on six to ten foot centers.

PLATE III

Cross-section of Canal showing Consolidation of Canal Banks

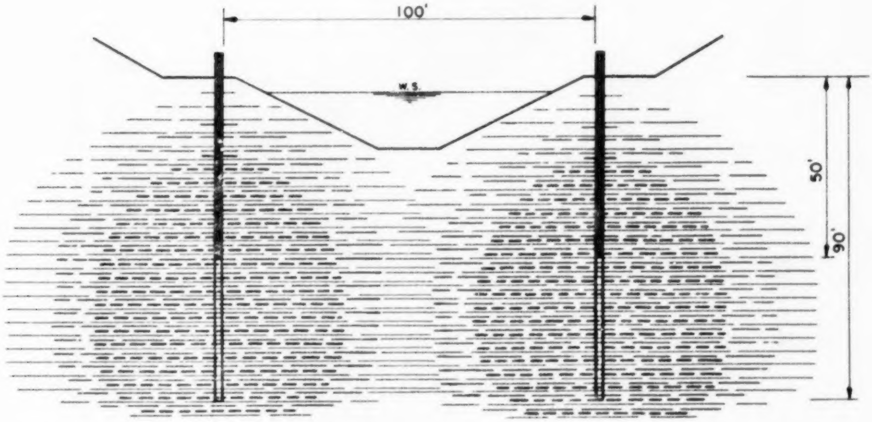


Plate III shows the cross-section of canal in loess soil and two lines of four inch holes drilled ninety feet deep and two two inch injection pipes extending fifty feet below the surface of the earth where sufficient silt has been pumped to consolidate the soil to prevent leakage.

PLATE XIV

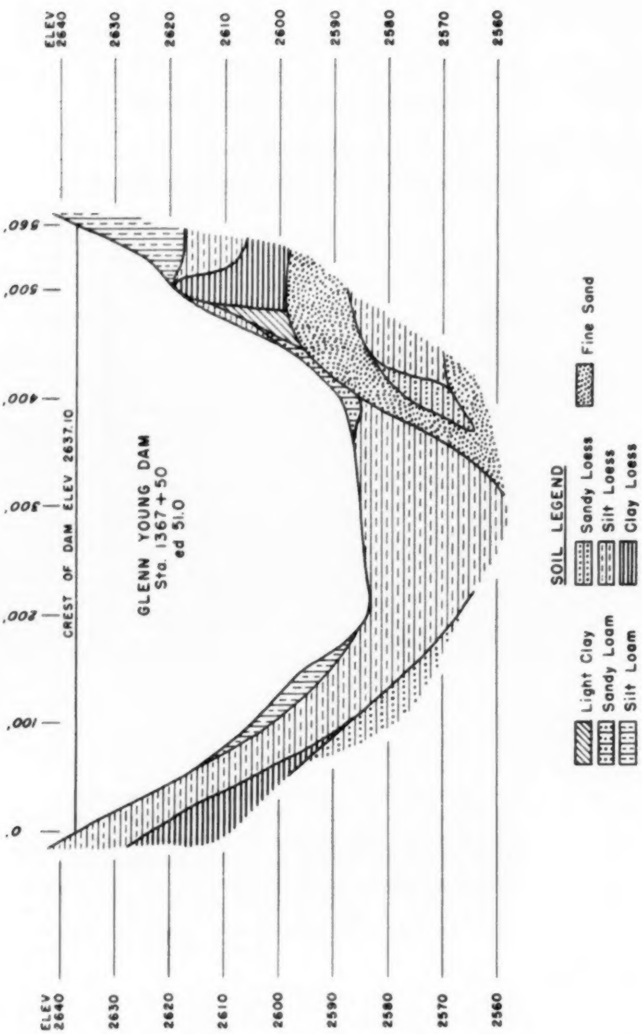

GLENN YOUNG DAM
Sta. 1367+50
ed 51.0
CREST OF DAM ELEV 2637.10
ELEV 2640
2630
2620
2610
2600
2590
2580
2570
2560
0'
100'
200'
300'
400'
500'
560'
SOIL LEGEND
Light Clay
Sandy Loam
Silt Loam
Sandy Loess
Silt Loess
Clay Loess
Fine Sand

PLATE XIX

PRESENT POWER DEVELOPMENT
BY
THE CENTRAL NEBRASKA PUBLIC POWER AND IRRIGATION DISTRICT
HASTINGS NEBRASKA

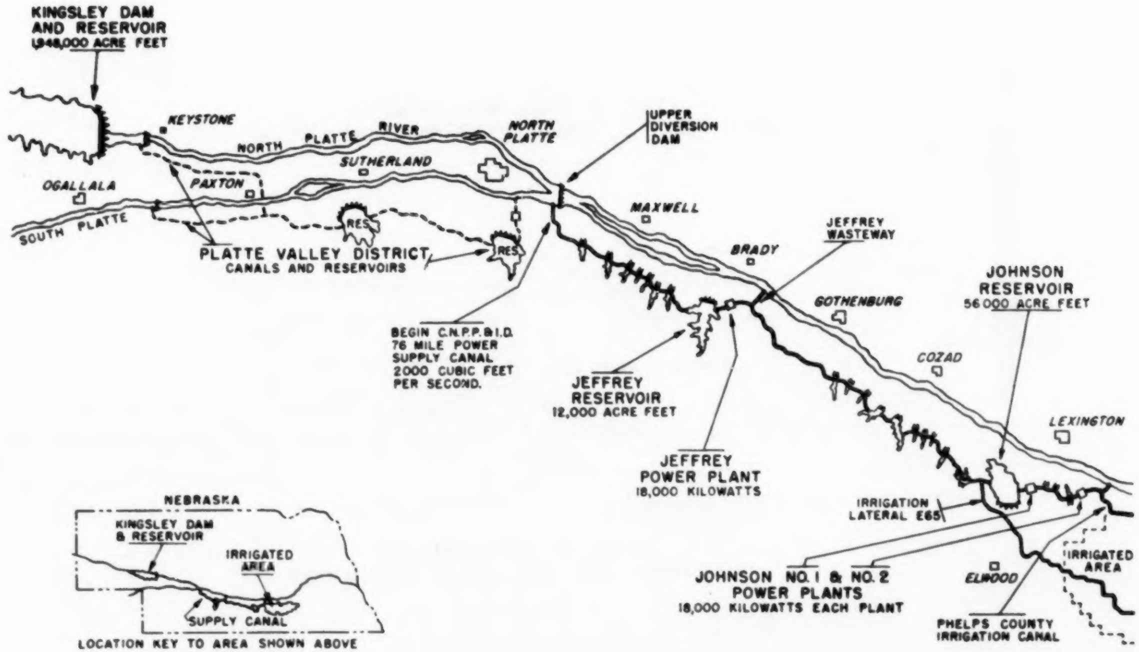
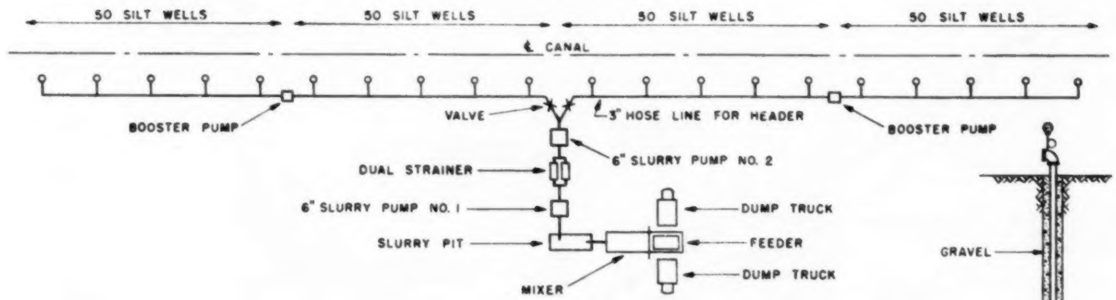
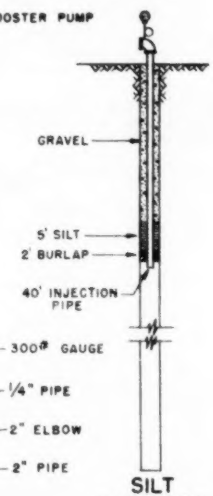


PLATE XX

EQUIPMENT SETUP FOR SILT INJECTION ON ONE SIDE OF CANAL





SILT INJECTION WELL

DETAIL OF CONNECTION FROM 3" HOSE LINE TO INJECTION PIPE IN WELL

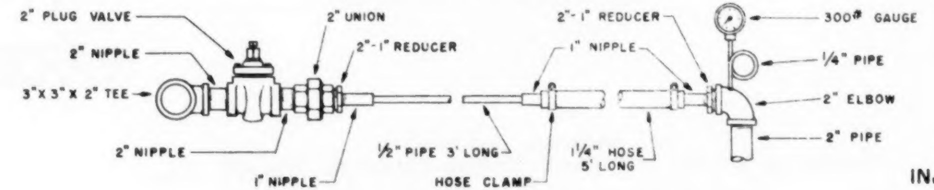
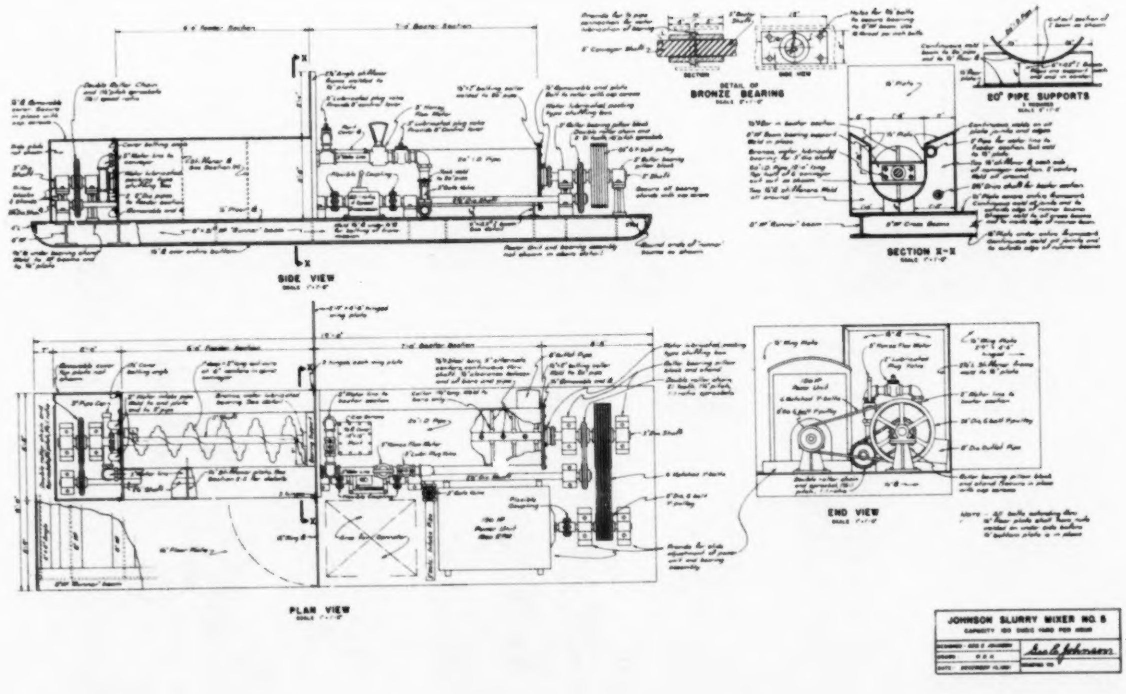


PLATE XXI

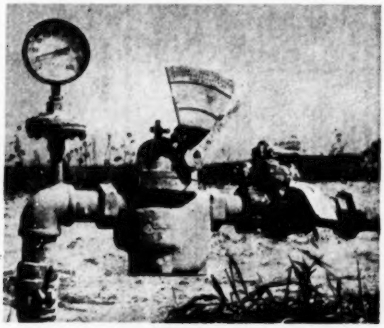

SIDE VIEW
PLAN VIEW
END VIEW
SECTION X-X
DETAIL OF BRONZE BEARING
20" PIPE SUPPORTS
JOHNSON SLURRY MIXER NO. 5
CAPACITY 100 CUBIC YARD PER HOUR

NO. 1—DRILLING SILT WELLS

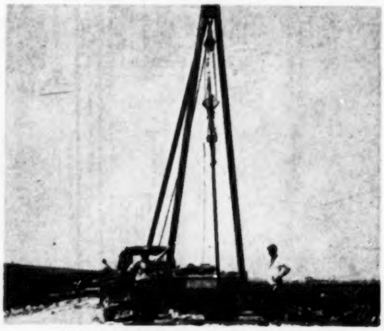
NO. 2—SPOIL BANK USED FOR SLURRY

NO. 3—MIXER AND PUMP SETUP

NO. 4—HOSE LINE HEADER



NO. 5—CONNECTION TO INJECTION PIPE



NO. 6—PULLING INJECTION PIPE